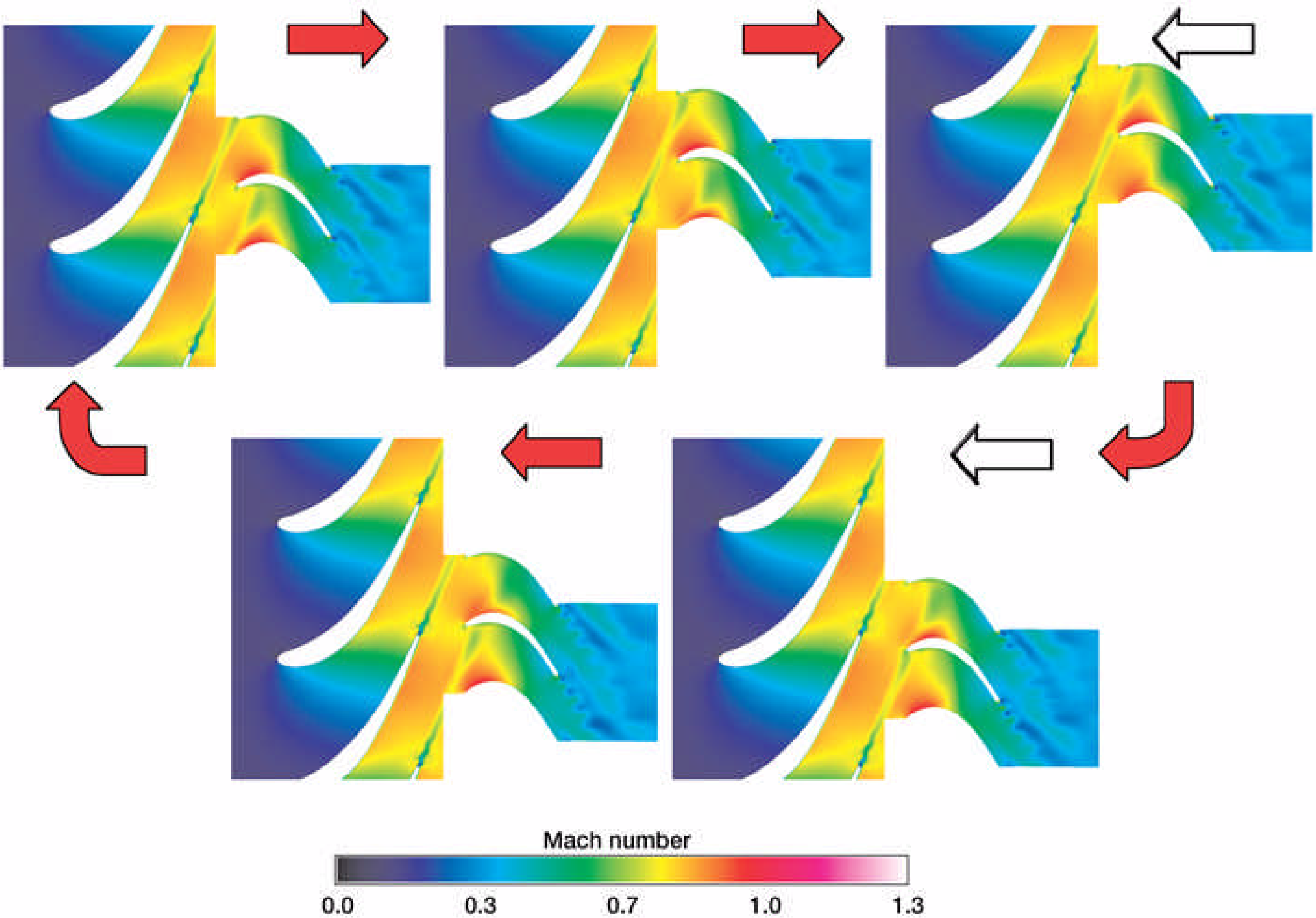
Unsteady Flowfield in a High-Pressure Turbine Modeled by TURBO



Unsteady flowfield in a high-pressure turbine stage shown as a sequence of five plots of instantaneous Mach number contours.

Forced response, or resonant vibrations, in turbomachinery components can cause blades to crack or fail because of the large vibratory blade stresses and subsequent high-cycle fatigue. Forced-response vibrations occur when turbomachinery blades are subjected to periodic excitation at a frequency close to their natural frequency. Rotor blades in a turbine are constantly subjected to periodic excitations when they pass through the spatially nonuniform flowfield created by upstream vanes. Accurate numerical prediction of the unsteady aerodynamics phenomena that cause forced-response vibrations can lead to an improved understanding of the problem and offer potential approaches to reduce or eliminate specific forced-response problems.

The objective of the current work was to validate an unsteady aerodynamics code (named TURBO) for the modeling of the unsteady blade row interactions that can cause forced-response vibrations. The three-dimensional, unsteady, multi-blade-row, Reynoldsaveraged Navier-Stokes turbomachinery code named TURBO was used to model a high-pressure turbine stage for which benchmark data were recently acquired under a NASA contract by researchers at the Ohio State University. The test article was an initial design for a high-pressure turbine stage that experienced forced-response vibrations which were eliminated by increasing the axial gap. The data, acquired in a short duration or shock tunnel test facility, included unsteady blade surface pressures and vibratory strains.

The unsteady flowfield was computed using the TURBO code for two axial gaps at resonant crossings of modes 2, 3, and 4. Two grids were used to evaluate the effects of spatial discretization. Numerical studies were performed to ensure that the computational results were nearly independent of the choice of numerical input parameters. Unsteady blade surface pressures were compared with data at 50- and 85-percent span, which were the locations of the pressure transducers in the experiment. In addition, plots of the flowfield were prepared to understand how the upstream vane wakes interacted with the downstream rotor (see the figure).

The computational results agreed quite well with the experimental data at both spanwise locations and at the various operating conditions. The mean loading was seen to be higher near the tip than at the midspan location. The trend was reversed for unsteady loading, with the higher unsteady loads occurring at the midspan. A comparison of the surface pressure for small and large gaps showed that the main pressure peak near the leading edge was smaller for the larger axial gap. This work has provided further validation of the TURBO code for unsteady aerodynamic computations of turbomachinery blade rows. The unsteady aerodynamic calculations described here were performed under a grant by a University of Toledo researcher in collaboration with NASA Glenn Research Center and Honeywell researchers.

Reference

1. Bakhle, Milind A., et al.: Calculation and Correlation of the Unsteady Flowfield in a High Pressure Turbine. NASA/TM--2002-211475, 2002.

University of Toledo contact: Dr. Milind A. Bakhle, 216-433-6037, Milind.A.Bakhle@grc.nasa.gov
Authors: Dr. Milind A. Bakhle and Oral Mehmed

Headquarters program office: OAT
Programs/Projects: Propulsion Systems R&T